PFA Studies in SiD

Andy White

University of Texas at Arlington

From talks given by Mat Charles
The University of Iowa
at the SLAC-SiD Workshop
and
Steve Magill at ALCPG07

Outline

- e goals
- atus & plans of PFA implementations
- ogress since October workshop
- D Detector Optimization using PANDORA/
- utlook

- ot in this talk (unless requested)
  - ntro & fundamentals of PFA

The goals

udy the physics performance of the detecto

. particularly the benchmark channels

otimize the detector design quantitatively

ake informed, rational technology choices

do these with confidence, we need a robus
gh-performance PFA.

Rule of thumb: dijet mass resolution ~ 3 to 4 GeV.

List of existing SiD PFAs

eve Magill: Track following + E/p clustering

Xia: Density-based clustering.

U/NICADD group: Directed tree clustering

t Charles: NonTrivialPFA & ReclusterDTree

ver, most PFA developers are working part time on – split betwe
tasks (BaBar, ATLAS, ILC Test Beam,…)

portant not to forget that there are other
ople working on modules, infrastructure,
nchmarking, tools, etc:

- Ron (tools PFA testing)
- ima (looking into PFA/tracking interface)
- ay, Lawrence (testing/benchmarking PFA output)
- ay, Marcel, George (PandoraPFA)
- ingmin (photon-finding)
- . and more besides (apologies!)

> ZZ -> qq + νν @ 500 GeV

elopment of PFAs on ~120 GeV jets – most common ILC jet
mbiguous dijet mass allows PFA performance to be evalua
jet combination confusion
performance at constant mass, different jet E (compare to
e)
E, dθ/θ -> dM/M characterization with jet E

> ZZ -> qqqq @ 500 GeV

e+e- ...

ts - same jet E, but filling more of detector
ne PFA performance as above?
for detector parameter evaluations (B-field, IR, granularity,
)

> tt @ 500 GeV

er E jets, but 6 – fuller detector

> qq @ 500 GeV

-> 1 TeV?

A developers meeting weekly – Wednesdays AM

Cassell, Dhiman Chakraborty, Mat Charles, Ray Cowan, Norma
, Guilherme Lima, Steve Magill, Jose Repond, Marcel Stanitzki,
y White, Lei Xia, Vishnu Zutshi

npower estimate ~3-4 FTE (ANL,NIU TestBeam
mmitments, e.g. Lei is 100% testbeam now)

ics normally discussed :

1) PFA Performance

2) Common development software tools

3) Comparison of algorithms and detectors

4) Definition/implementation of standard input/output

5) Timescales for performance measures

tep 1: Find photons, remove their hits.

- Tight clustering
- Apply shower size, shape, position cuts (very soft photons fail these)
- Make sure that they aren't connected to a charged track

tep 2: Identify MIPs/track segments in calorimeters. Identify dense clump ts.

- These are the building blocks for hadronic showers
- Pretty easy to define & find

tep 3: Reconstruct skeleton hadronic showers

- Coarse clustering to find shower components (track segments, clumps) that are nearby
- Use geometrical information in likelihood selector to see if pairs of components are connected
- Build topologically connected skeletons
- If >1 track connected to a skeleton, go back and cut links to separate
- Muons and electrons implicitly included in this step too

tep 4: Flesh out showers with nearby hits

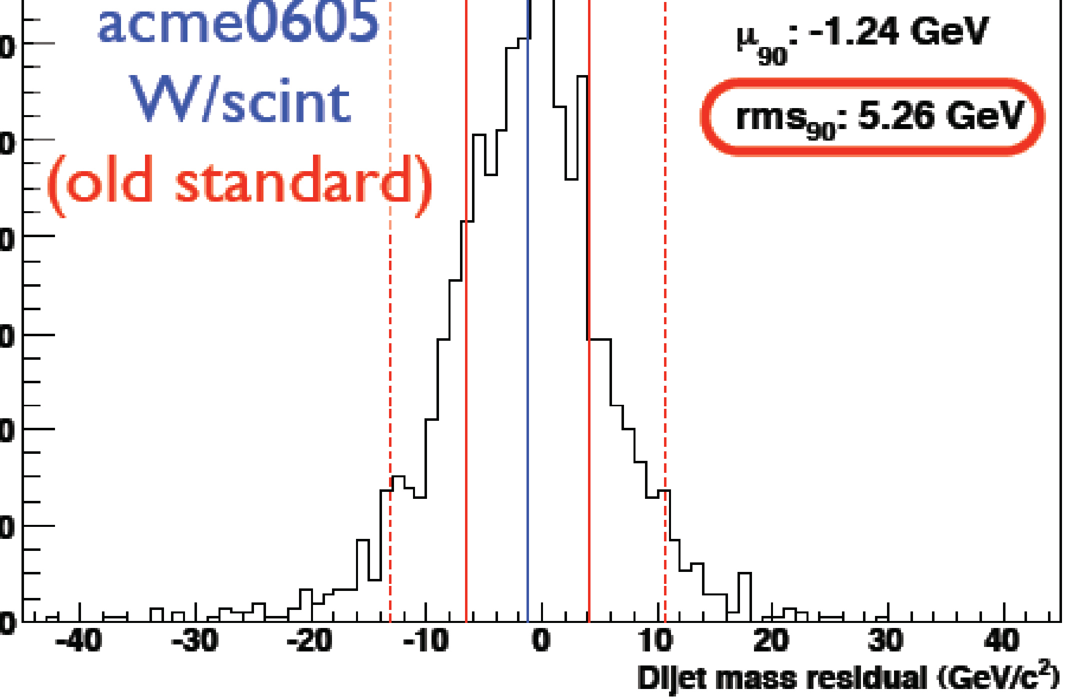
- Proximity-based clustering with 3cm threshold

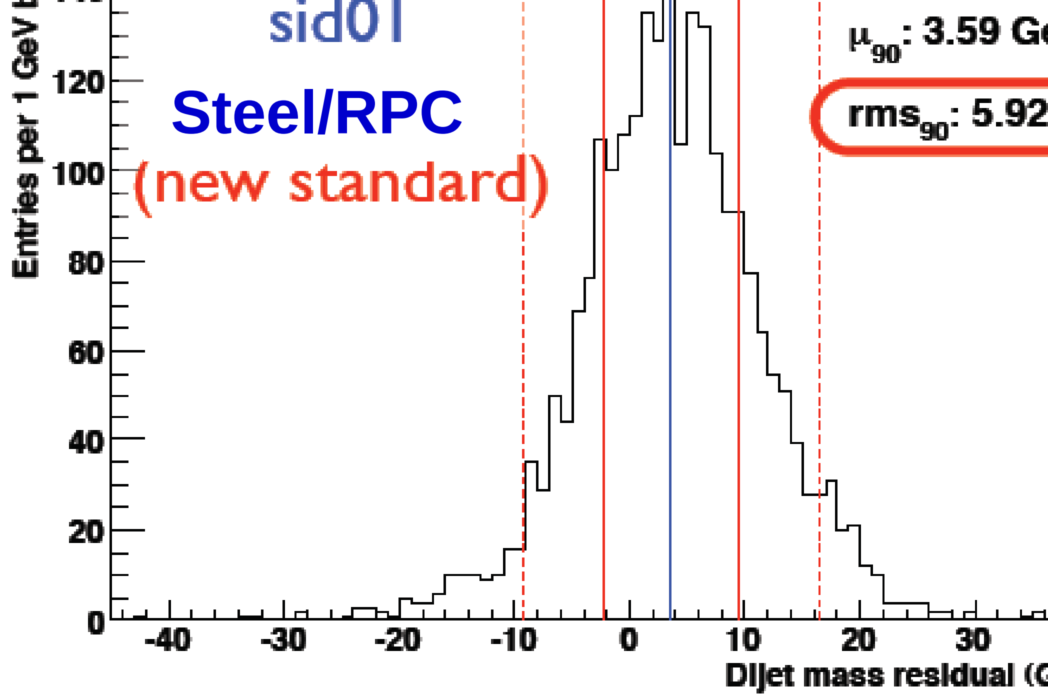
tep 5: Identify charged primaries, neutral primaries, soft photons, fragme

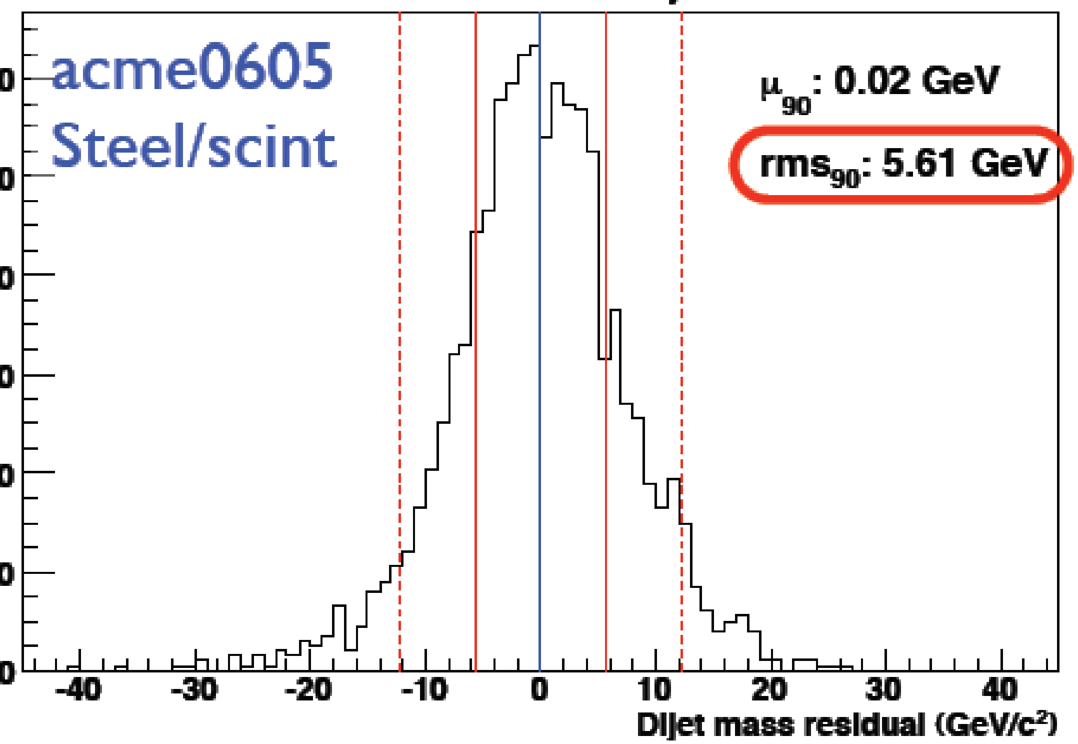
- Extrapolate tracks to clusters to find charged primaries
- Look at size, pointing, position to discriminate between other cases
- Merge fragments into nearest primary
- Use E/p veto on track-cluster matching to reject mistakes (inefficient but mostly unbiased)
- Use calibration to get mass for neutrals & for charged clusters without a track match (calibrations for EM, hadronic provided by Ron Cassell)

nown issues & planned improvements:

- Still some cases when multiple tracks get assigned to a single cluster
- Punch-through (muons and energetic/late-showering hadrons) confuses E/p cut
- Improve photon reconstruction & ID
- Improve shower likelihood (more geometry input)
- Use real tracking when available
- No real charged PID done at this point







Something changed here & I lost ground.

It's not obvious what -- material details, extra layer in ECAL, artifact of algorithm, ...

requiring primary quarks have |cos(theta)|<0.8

Progress since October

e Magill's PFA

proved clustering (now using DTree); new results coming

s NonTrivial PFA & ReclusterDTreePFA

cus is on new algorithm (using reclustering as advertised
ctober)

provements in resolution over past 3 months; now doing
an previous algorithm. (See next slides.)

ll quite a long way to go.

T group (Ray Cowan + Lawrence Bronk) have just starte
ogram of running PFA on detector design variants.

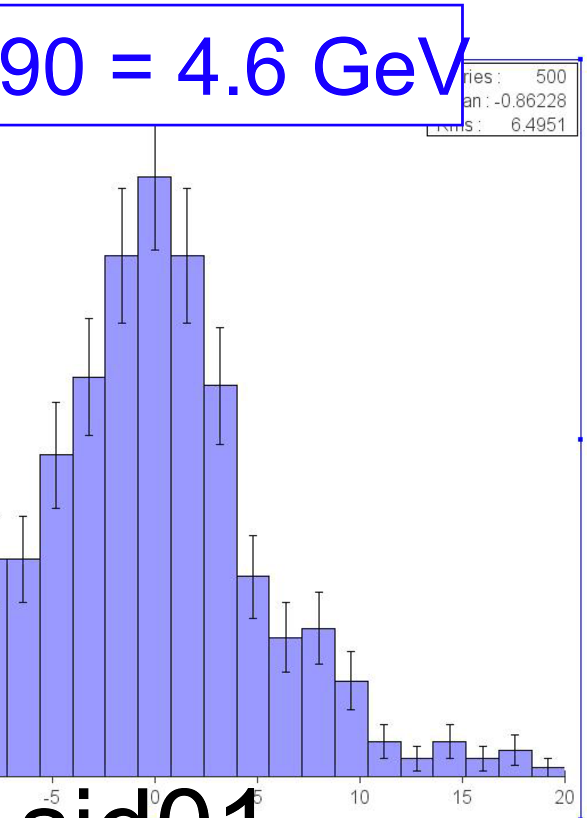
also Ron & Marcel's talks, and talks in PFA parallel sess

urrent implementation (updated since Octob
Track-MIP association
Track-cluster association (DT clustering, E/p)
Photon finding (DT & NN clustering, H-matrix ID)
Neutral hadron finding (DT clustering, cluster merg
w/ cone algorithm)

gorithm parameters tuned only on single-
rticle events (W/Scint HCAL). Process-
dependent!

eve plans to release code soon (after final

owing dijet invariant mass for events with |cosθ|<0
KT algorithm used to find 2 jets.

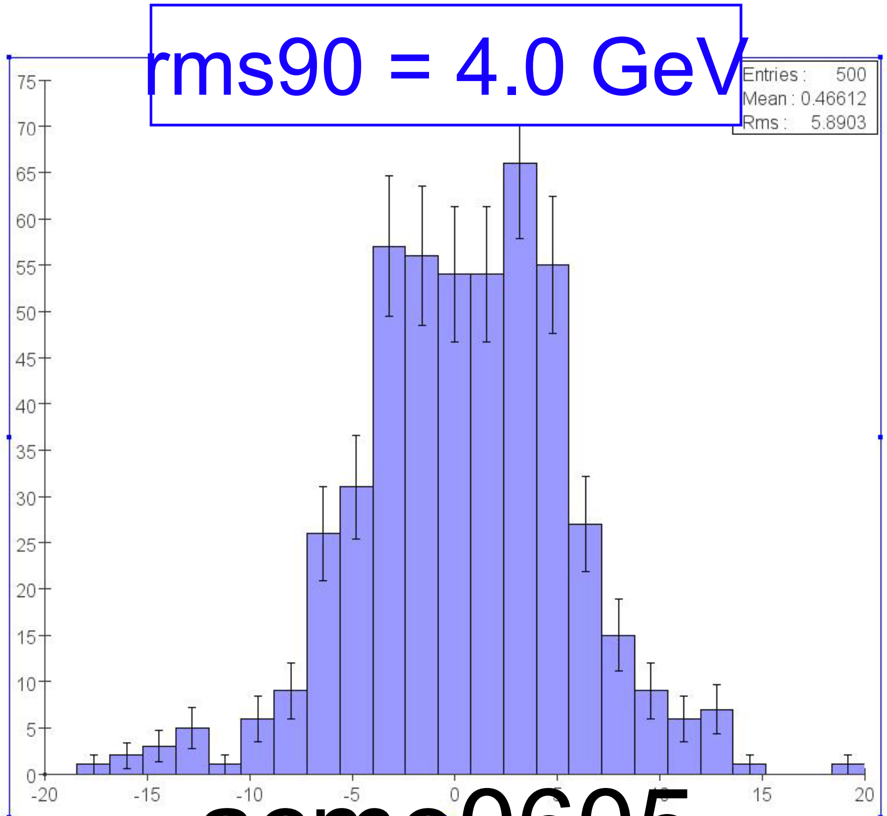


sid01

el/RPC HCAL

CAL radius

125cm

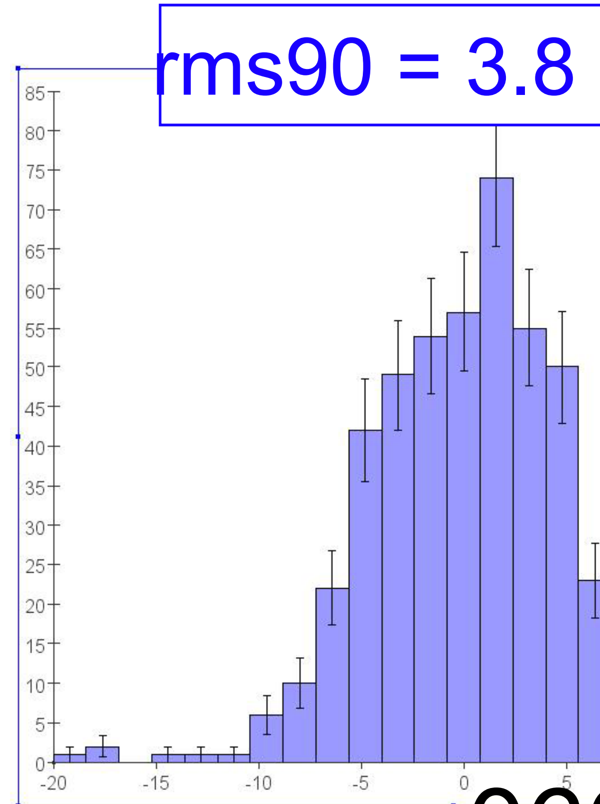


acme0605

W/Scint HCAL

ECAL radius

125cm



acme060

W/Scint HC

ECAL radiu

175cm

CAL helps a lot for this algorithm.

vasn't the case for perfect PFA... possibly due to E/p checking?

gress (Iowa): Algorithm developm

v(ish) approach: iterative reclustering

ic premise presented at FNAL in October:

reak hadronic showers into digestible pieces.

se geometrical information to link them...

taking into account E/p and other nearby showers.

v coded up & running. Approach has evolved:

se fuzzy clustering to for unassigned hits (fragments)

se DirectedTree clusterer to define "envelope" clusters

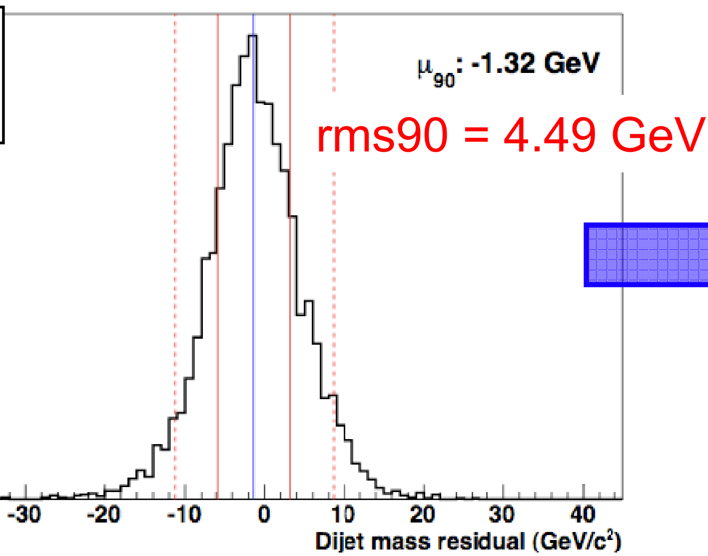
troduce E/p veto if wrong by more than 2.5σ

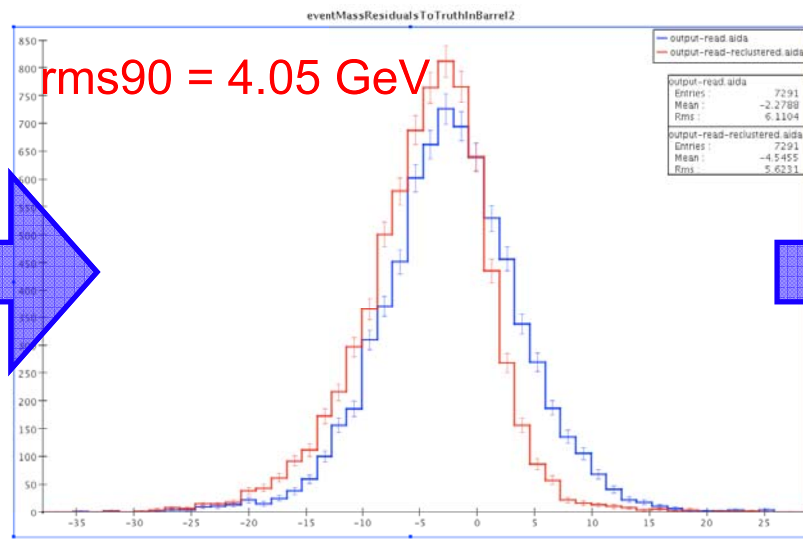
ecoded MIP-finder to do better with shower "tentacles"

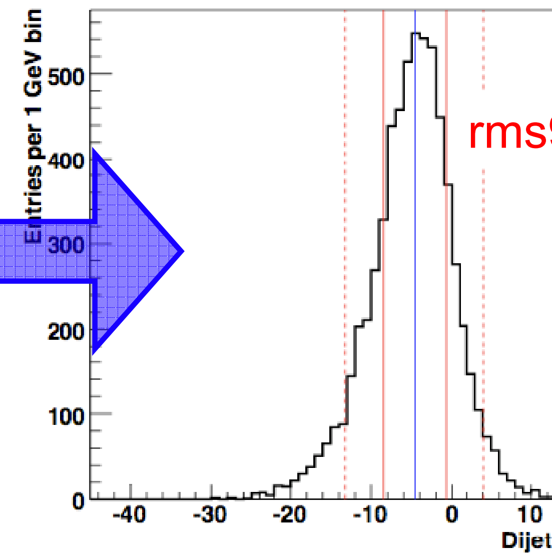
ggressive second pass to match clusters to tracks owing dijet invariant mass for events with |cosθ|<0

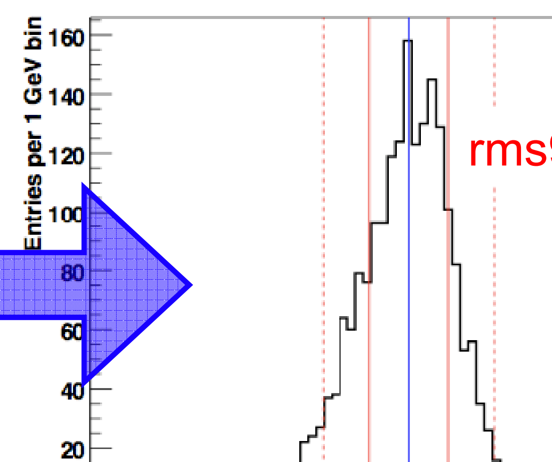
Detector design: sid01 (Steel/Scint HCAL)

NonTrivialPFA (previous algorithm)	Reclustering Shown on Nov 28th	Reclustering- Shown on Ja









...me useful tools:

- ...on's cluster analysis package (picks out confusion matrix)
- ...heaters for various pieces
- ...lobal chi2 based on E/p (not quite trustworthy yet...)

...ans & known problems:

- ...urrently limited to rms90 ~ 4.3 GeV even when cheating on ...nkage -- need to understand why & break through.
  - Candidate: Some fragments get thrown away => lose neutral energy
  - Candidate: Large clumps that should be broken up/shared but are treated ... single lump
  - Candidate: Impurities in photon list
  - Candidate: E/p goes bad for muons & punch-through

[Ron is helping with t...

- ...ver-aggressive assignment of clusters to tracks can force ...istakes

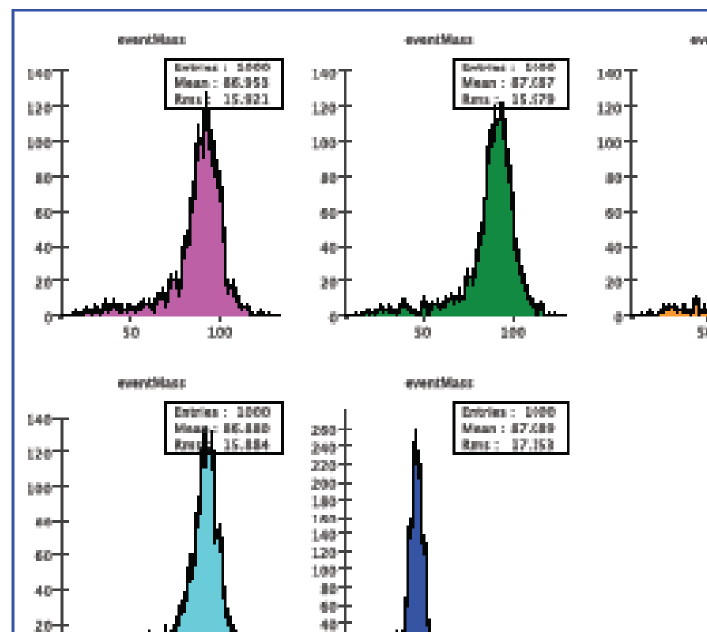
ot at the point where PFA can unambiguously say which
or design is better.

Z-pole results

rms_{90}	sid01	acme06
Steve PFA	4.6 GeV	4.0 Ge
NonTrivialPFA	4.5 GeV	4.1 Ge
ReclusterDTree	3.9 GeV	3.9 Ge

important to start thinking about this now, doing tri
ooking for obvious patterns

MIT group (Ray & Lawrence) just got started on survey of design variants with Iowa PFA code.
[Example: # HCAL layers]



SiD
obal Parameter Optimizatio
using Pandora PFA

28.01.2007

M. Stanitzki

STFC-Rutherford Appleton Laboratory

The Idea

Use the current best Particle Flow Algorithm

- PandoraPFA by Mark Thomson

Start optimizing SiD

- r,z,T,
- layers, segmentation
- material, technology

More Difficult

Caveat : Only works within Marlin Framework

No SiD detector model available in this framework

Have to use a SiD look-alike, the SiDish

PandoraPFA

- Developed by Mark Thomson
- The world's best so far (V2.0 available)
- Pandora is monolithic
  - Calibration
  - Clustering
  - MIP/Photon Finder
  - Particle Flow
- Well tailored towards LDC00Sc and (most recent) LDC01_05Sc

The Setup

- Use PandoraPFA 2.0 & LCPHYS
- Start of with LDC00Sc (Reference Point)
- Then go to SIDish
- Use track cheating
  - tracking shouldn't matter ... to first order
- Vary parameters
  - radius
  - Z
  - field
  - layers
  - ...

The "SIDish"

- racker radius=1.25m
- racker Z=1.7 m
- CAL SiW 20+10 layers, 1x1 cm tiles
- CAL Fe-Scint 40 layers 3x3 cm tiles
- ame Calorimeter layout as LDC00Sc (besides 30+10
20+10)
- T Field

Detector TAG	B-field	ECAL layers	ECAL cell size	HCAL layers	HCAL cell size	Tracker radius	Tracker le
C00	4	40	1x1	40	3x3	1690	
ish	5	30	1x1	40	3x3	1250	
ish_r10_z17	5	30	1x1	40	3x3	1000	
ish_r15_z17	5	30	1x1	40	3x3	1500	
ish_r125_z15	5	30	1x1	40	3x3	1250	
ish_r125_z19	5	30	1x1	40	3x3	1250	
ish_4T	4	30	1x1	40	3x3	1250	
ish_6T	6	30	1x1	40	3x3	1250	
ish_hcal50	5	30	1x1	50	3x3	1250	
ish_hcal60	5	30	1x1	60	3x3	1250	
sh_ecal40	5	40	1x1	40	1x1	1250	
sh_hcal_cu	5	30	1x1	40	1x1	1250	

Done with different Mokka Version (slight inconsistency)

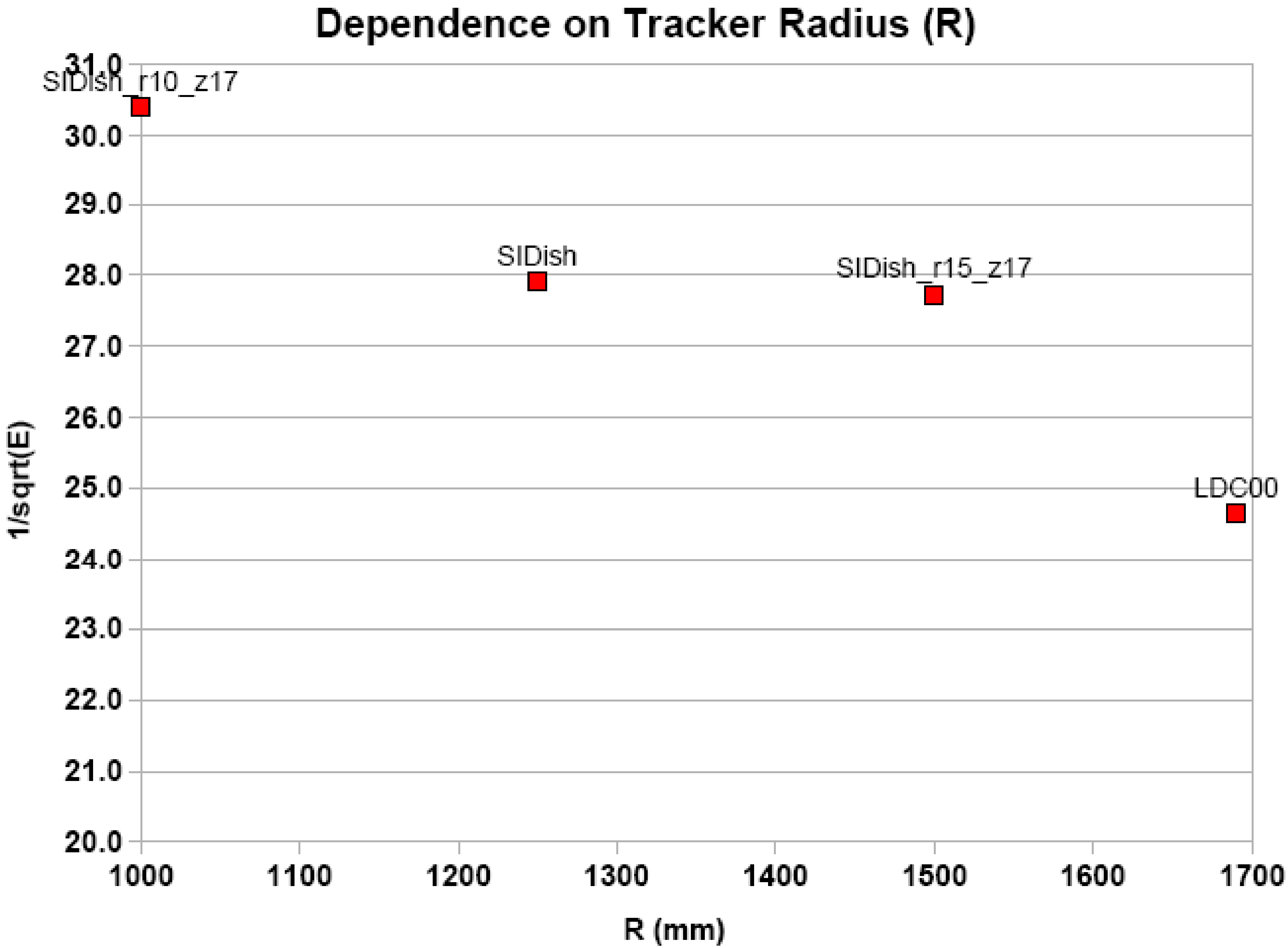
Preliminary Results

ctor TAG	B-field	Tracker radius	Tracker length	rms90 (uds45)	E
00	4	1690	2730	24.6	
sh	5	1250	1700	27.9	
sh_r10_z17	5	1000	1700	30.4	
sh_r15_z17	5	1500	1700	27.7	
sh_r125_z15	5	1250	1500	29.0	
sh_r125_z19	5	1250	1900	28.5	
sh_4T	4	1250	1700	28.9	
sh_6T	6	1250	1700	28.6	
sh_hcal50	5	1250	1700	28.7	
sh_hcal60	5	1250	1700	28.7	

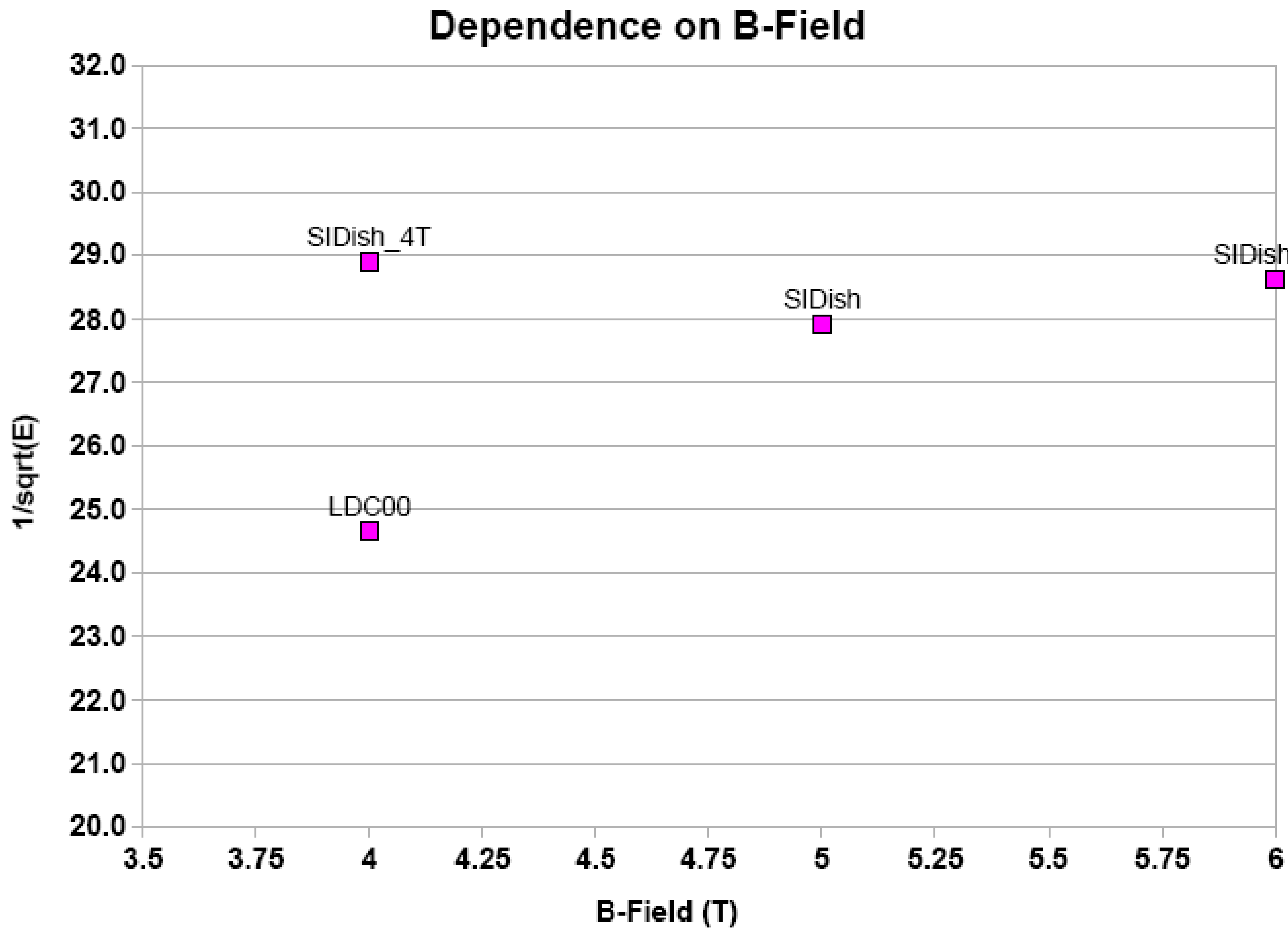
PRELIMINARY

Done with different Mokka Version (slight inconsistency)

R dependence (Barrel)



B field dependence (Barre



Other things on the radar

- ual-readout
  - Promising idea (for both confusion and σ_{NH} terms)
  - Software issue: Tricky to implement in our framewo
  - See Adam's talk this afternoon
- acking improvements

is critical for SiD (& most generic LC detectors)

en near-term manpower, very unlikely to meet original LC
edule – but now aiming for April 2009.

nded schedule (+6 months) is not a sign to relax!

we are serious about SiD, must not lose momentum on F

e may actually have less (time×manpower) than before.

ent PFA experts will not be around forever

itical to maintain expertise (takes a long time to develop)

eed to consciously recruit & train new experts.

tal to consolidate progress & make it accessible to others

it your code in CVS! Document it! Get others using it!

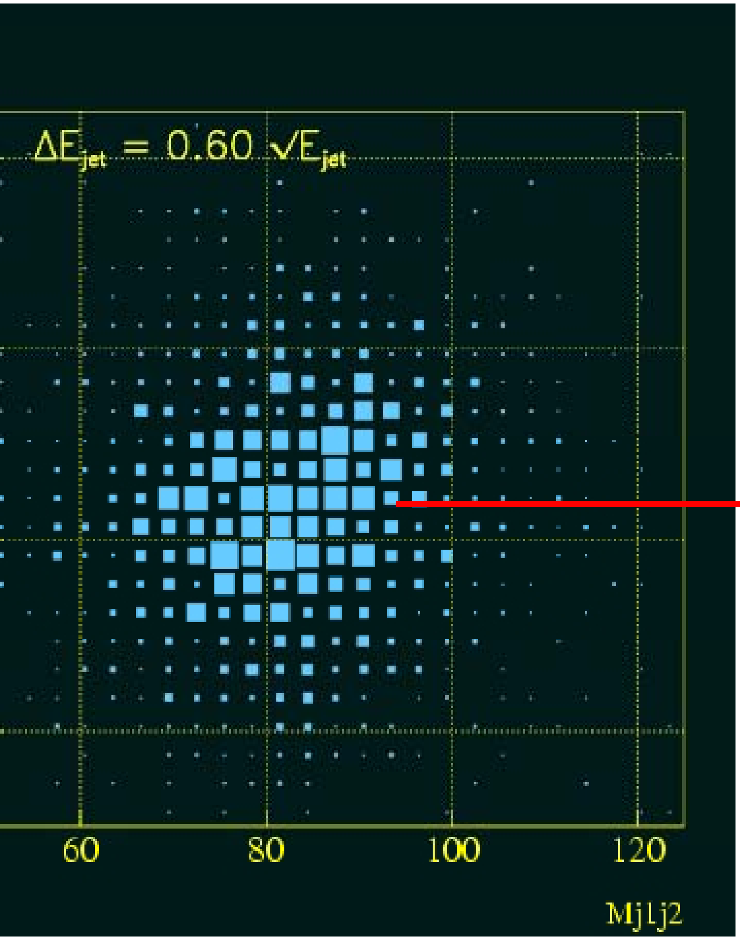
eneral interest in writing a NIM, though no concrete plans

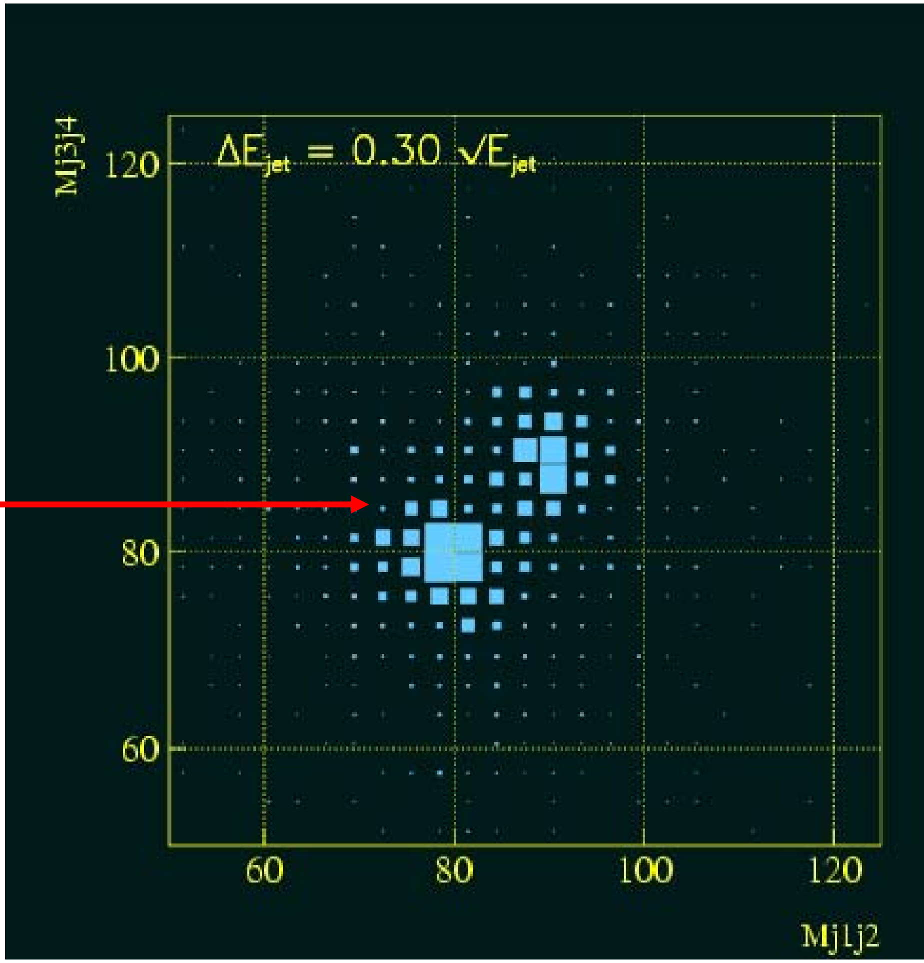
pite the gloom, we are making progress!

EXTRA SLIDES:

PFA INTRODUCTION

sing only energy measurements based on th
calorimeter systems)





60%/√E

30%/√E

Target region for je

ualized EM and HAD responses ("compensation")

otimized sampling fractions

AMPLES:

EUS - Uranium/Scintillator

Single hadrons 35%/√E ⊕ 1%

Electrons 17%/√E ⊕ 1%

Jets 50%/√E

) – Uranium/Liquid Argon

Single hadrons 50%/√E ⊕ 4%

Jets 80%/√E

rgy Flow approach holds promise of required soluti
has been used in other experiments effectively –
remains to be proved for the Linear Collider!

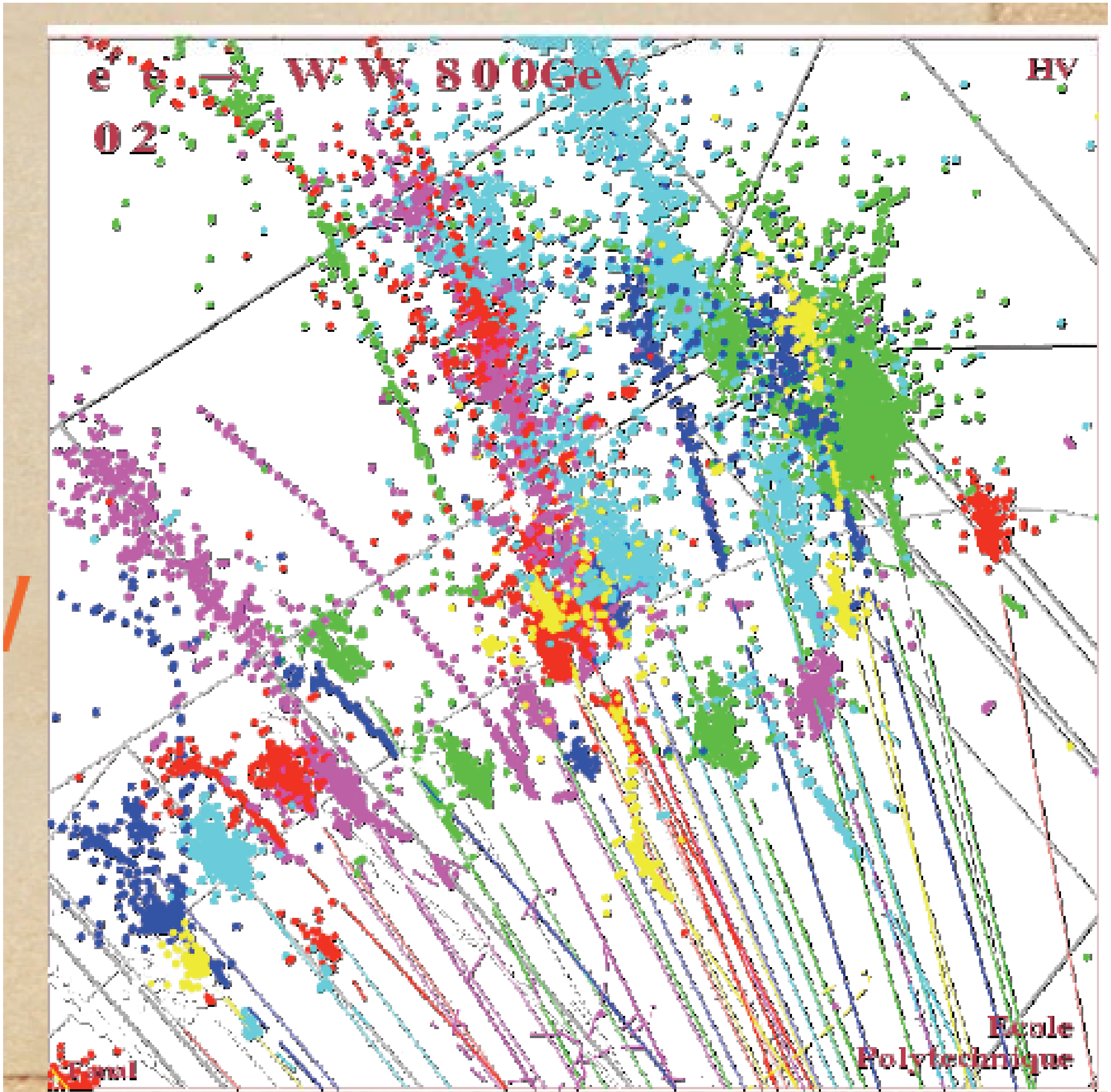
se tracker to measure Pt of dominant, charged
ticle energy contributions in jets; photons measure
l.

eed efficient separation of different types of ene
osition throughout calorimeter system

nergy measurement of only the relatively small neu
ron contribution de-emphasizes intrinsic energy
olution, but highlights need for very efficient "pat
ognition" in calorimeter.

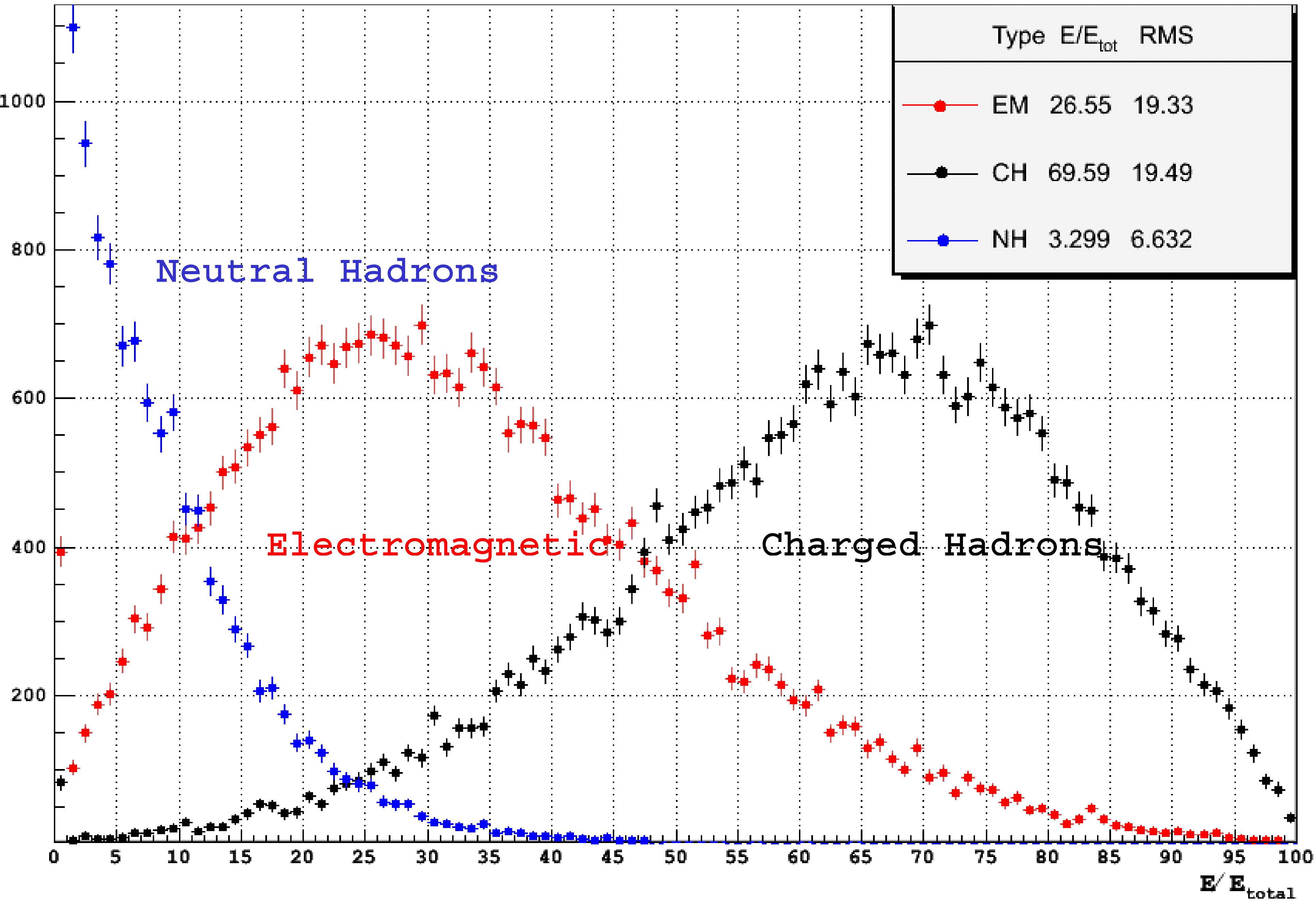
easure (or veto) energy leakage from calorimeter

Don't underestimate the complexity!



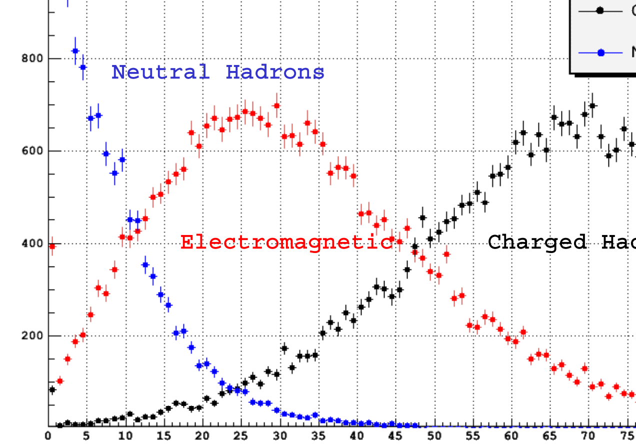
T.Takeshita-LCWS2004@Paris

Fraction Energy of Particles in Jets



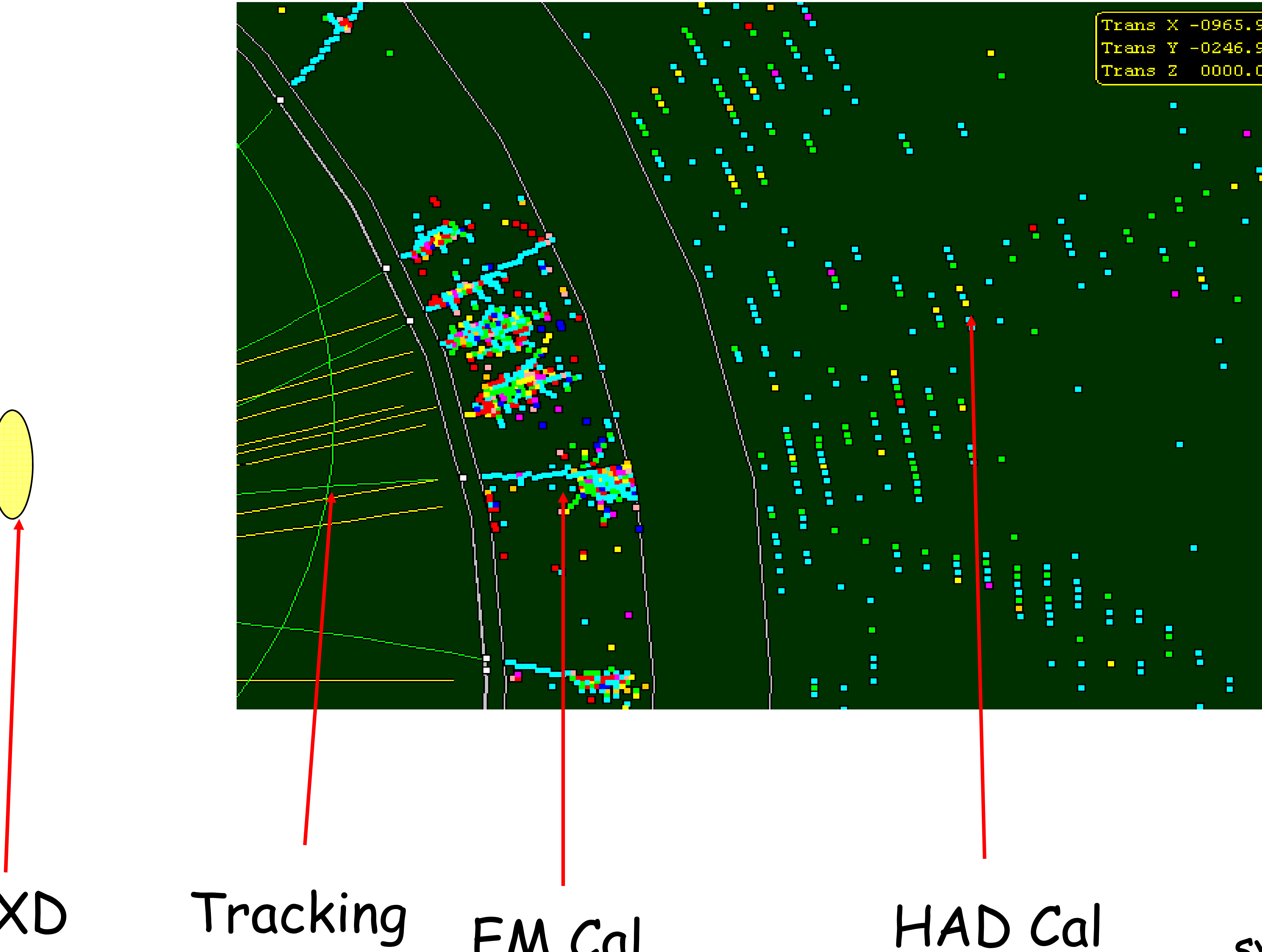
- It is popular to quote the
es of these distributions, however

are wide variations, and we will
o develop efficient procedures for
with e.g.



25% neutral hadrons,
40% EM (all photons?),
35% Charged hadrons

allenging task to find all neutral clusters (and *not*
associate them with a track!)


Tracking
HAD Cal

Integrated Detector Design

now we must consider the detector as a *whole.*

e tracker not only provides excellent momentum
solution (certainly good enough for replacing cluste
ergies in the calorimeter with track momenta), but
o must:

fficiently find all the charged tracks:

ny missed charged tracks will result in the
orresponding energy clusters in the calorimeter
eing measured with lower energy resolution *and*
potentially larger confusion term.

vide excellent two track resolution for correct
k/energy cluster association

acker outer radius/magnetic field size – implicatio
.m. shower separation/Moliere radius in ECal.

ferent technologies for the ECal and HCal

we lose by not having the same technology?

mpensation – is the need for this completely overc
ing the energy flow approach?

Integrated Detector Design

rvices for Vertex Detector and Tracker should no
e large penetrations, spaces, or dead material with
calorimeter system - implications for inner system
gn.

orimeters should provide excellent MIP identifica
muon tracking between the tracker and the muon
em itself. High granularity digital calorimeters sho
rally provide this - but what *is* the granularity
irement?

e must be able to find/track low energy (< 3.5 GeV
ns completely contained inside the calorimeter.

Identify and measure each jet energy component as well as possible

owing charged particles through calorimeter dema
high granularity...

options explored in detail:

Analog ECal + Analog HCal

- for HCal: cost of system for required granular

Analog ECal + Digital HCal

- high granularity suggests a digital HCal solutio
- resolution (for residual neutral energy) of a pu